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(54) **Process for rejuvenating a diffusion aluminide coating**

Verfahren zur Wiederherstellung von Diffusions-Aluminid-Beschichtung

Procédé de réactivation d'un revêtement d'alumine obtenu par diffusion

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Description

[0001] This invention relates to diffusion coatings for components exposed to oxidizing and corrosive environments, such as the hostile environment of a gas turbine engine. More particularly, this invention is directed to a process for rejuvenating a platinum-containing diffusion aluminide coating without entirely removing the coating from a substrate.

[0002] Higher operating temperatures for gas turbine engines are continuously sought in order to increase their efficiency. However, as operating temperatures increase, the high temperature durability of the components of the engine must correspondingly increase. Significant advances in high-temperature capabilities have been achieved through the formulation of nickel and cobalt-base superalloys, though without a protective coating components formed from superalloys typically cannot withstand long service exposures if located in certain sections of a gas turbine engine, such as the turbine, combustor and augmentor. One such type of coating is referred to as an environmental coating, i.e., a coating that is resistant to oxidation and hot corrosion. Environmental coatings that have found wide use include diffusion aluminide coatings formed by diffusion processes, such as a pack cementation and vapor phase processes.

[0003] Diffusion processes generally entail reacting the surface of a component with an aluminum-containing gas composition to form two distinct zones, the outermost of which is an additive layer containing an environmentally-resistant intermetallic represented by MAI, where M is iron, nickel or cobalt, depending on the substrate material. The MAI intermetallic is the result of deposited aluminum and an outward diffusion of iron, nickel and/or cobalt from the substrate. During high temperature exposure in air, the MAI intermetallic forms a protective aluminum oxide (alumina) scale that inhibits oxidation of the diffusion coating and the underlying substrate. The chemistry of the additive layer can be modified by the presence in the aluminum-containing composition of additional elements, such as platinum, chromium, silicon, rhodium, hafnium, yttrium and zirconium. Diffusion aluminide coatings containing platinum, referred to as platinum aluminide coatings, are particularly widely used on gas turbine engine components. Platinum is typically incorporated into the coating by electroplating a layer of platinum on the substrate prior to aluminizing, yielding an additive layer that includes (Pt)NiAl-type intermetallic phases, usually PtAl₂ or platinum in solution.

[0004] The second zone of a diffusion aluminide coating is formed in the surface region of the component beneath the additive layer. The diffusion zone contains various intermetallic and metastable phases that form during the coating reaction as a result of diffusional gradients and changes in elemental solubility in the local region of the substrate. The intermetallics within the diffusion zone are the products of all alloying elements of the substrate and diffusion coating.

[0005] Though significant advances have been made with environmental coating materials and processes for forming such coatings, there is the inevitable requirement to repair these coatings under certain circumstances. For example, removal may be necessitated by erosion or thermal degradation of the diffusion coating, refurbishment of the component on which the coating is formed, or an in-process repair of the diffusion coating or a thermal barrier coating (if present) adhered to the component by the diffusion coating. The current state-of-the-art repair process is to completely remove a diffusion aluminide coating by treatment with an acidic solution capable of interacting with and removing both the additive and diffusion layers. An example of such a process is disclosed in commonly-assigned U.S. Patent No. 3,833,414 to Grisik et al. The Grisik process relies on lengthy exposures to an aqueous solution of nitric and phosphoric acids, followed by treatment with an alkaline permanganate solution to completely remove the coating.

[0006] Removal of the entire aluminide coating, which includes the diffusion zone, results in the removal of a portion of the substrate surface. For gas turbine engine blade and vane airfoils, removing the diffusion zone can cause alloy depletion of the substrate surface and, for air-cooled components, excessively thinned walls and drastically altered airflow characteristics to the extent that the component must be scrapped. Therefore, rejuvenation processes have been developed for situations in which a diffusion aluminide coating must be refurbished in its entirety, but removal of the coating is not desired or allowed because of the effect on component life. Rejuvenation processes generally entail cleaning the surface of a component, followed by a controlled-activity aluminizing process that deposits additional aluminum on the component.

[0007] On occasion, excessive coating is deposited by rejuvenation processes, for example, the additive layer has a thickness in excess of about 100 micrometers. If the component has not been previously refurbished by completely removing its aluminide coating, the entire coating (i.e., additive layer and diffusion zone) can be fully stripped and the component re-aluminized. However, if the component has been previously refurbished by having its aluminide coating completely removed, thereby reducing its wall thickness, it may be necessary to scrap the component.

[0008] From the above, it can be appreciated that improved methods for refurbishing a diffusion aluminide coating are desired, particularly for those components that have undergone rejuvenation to have an excessively thick aluminide coating.

[0009] The present invention generally provides a process of rejuvenating a platinum-containing diffusion aluminide coating on a component designed for use in a hostile environment, such as superalloy turbine, combustor and augmentor components of a gas turbine engine. The rejuvenation process of this invention involves removing part or all of the additive layer of a platinum-con-

taining diffusion aluminide coating with minimal attack of the underlying diffusion zone, such that alloy depletion and thinning of the underlying substrate does not occur. The component is then re-aluminized to restore the additive layer of the coating. While potentially useful for a variety of situations, the process of this invention is particularly applicable to a platinum-containing diffusion aluminide coating that has been recently deposited on a component before the component has been placed in service, and particularly to a coating that was rejuvenated but the resulting additive layer was deposited to an excessive thickness. In this case, because the coating has not seen service, such as in the elevated temperatures of a gas turbine engine, limited interdiffusion has occurred between the component substrate and the additive layer.

[0010] The process of this invention involves treating the platinum-containing diffusion aluminide coating with an aqueous solution consisting essentially of nitric acid and phosphoric acid at a temperature of 70°C to 80°C until at least part of the additive layer has been removed but the substrate remains unaffected. The exposed treated surface of the component is then aluminized to deposit additional aluminum to build up the additive layer to a desired thickness.

[0011] According to the invention, the solution of nitric and phosphoric acids at the temperature used in the treatment step does not completely remove the diffusion aluminum coating, as has been the practice with prior art stripping methods. Instead, limited use of the acid solution is capable of cleanly removing the additive layer of a platinum-containing diffusion aluminide coating without attacking the substrate, such that alloy depletion and wall thinning of the substrate does not occur. As such, the reliability and service life of components refurbished by the process of this invention are significantly improved over that possible with prior art methods. While not wishing to be held to any theory, it is believed that the substrate is not attacked because the acid solution is selective to aluminum at the prescribed temperatures and the platinum content of the coating appears to act as a catalyst for the selective removal of aluminum. The process of this invention is most effective with a diffusion aluminide coating having only limited interdiffusion, such that the additive layer and the diffusion zone are well defined, as is the case when the diffusion aluminide coating on a gas turbine engine has been rejuvenated but before the component has been returned to engine service. As discussed above, a notable example of such a situation is when a coating has been rejuvenated but the resulting additive layer is excessively thick for its intended application.

[0012] The invention will now be described in greater detail, by way of example, with reference to the drawings, in which:-

Figure 1 is a perspective view of a high pressure turbine blade of a gas turbine engine.

Figure 2 represents a cross-sectional view of a diffusion aluminide coating on the blade of Figure 1.

[0013] The present invention is generally applicable to components that are protected from a thermally and chemically hostile environment by a platinum-containing diffusion aluminide coating. Notable examples of such components include the high and low pressure turbine nozzles and blades, shrouds, combustor liners and augmentor hardware of gas turbine engines. While the advantages of this invention are particularly applicable to gas turbine engine components, the teachings of this invention are generally applicable to any component on which a platinum-containing diffusion aluminide coating may be used to protect the component from its environment.

[0014] An example of a high pressure turbine blade 10 is shown in Figure 1. The blade 10 generally has an airfoil 12 and platform 16 against which hot combustion gases are directed during operation of the gas turbine engine, and whose surfaces are therefore subjected to severe attack by oxidation, corrosion and erosion. The airfoil 12 is anchored to a turbine disk (not shown) with a dovetail 14 formed on a root section of the blade 10. Cooling holes 18 are present in the airfoil 12 through which bleed air is forced to transfer heat from the blade 10. Particularly suitable materials for the blade 10 include nickel and cobalt-base superalloys, though it is foreseeable that other materials could be used.

[0015] Represented in Figure 2 is a diffusion aluminide coating 20 overlying a substrate region of the airfoil 12. A typical thickness for a diffusion aluminide coating used on gas turbine engine components is about 50 to about 125 micrometers. As known in the art, the diffusion aluminide coating 20 is formed by an aluminizing process, such as pack cementation, vapor phase (gas phase) aluminizing (VPA), or chemical vapor deposition (CVD), though it is foreseeable that other techniques could be used. Diffusion aluminide coating compositions are oxidation-resistant and form an alumina (Al_2O_3) layer or scale (not shown) on their surfaces during exposure to elevated temperatures. The alumina scale protects the underlying superalloy substrate from oxidation and hot corrosion.

[0016] The coating 20 is schematically represented in Figure 2 as being composed of an additive layer 22 overlying the surface of the blade 10, and a diffusion zone 24 in the surface region of the blade 10, as is typical for all diffusion aluminide coatings. The diffusion zone (DZ) 24 contains various intermetallic and metastable phases that form during the coating reaction as a result of diffusional gradients and changes in elemental solubility in the local region of the substrate. The additive layer 22 is typically about 30 to 75 micrometers thick and contains the environmentally-resistant intermetallic phase MAI, where M is iron, nickel or cobalt, depending on the substrate material (mainly b(NiAl) if the substrate is Ni-base). The additive layer 22 also contains (Pt)NiAl-type inter-

metallic phases.

[0017] Diffusion aluminide coatings of the type described above are the most widely used environmental coating for protecting turbine hardware because of their relatively low cost, simple equipment and coating operations, and the ability to be deposited without plugging air cooling holes. Due to high material and manufacturing costs, superalloy components having damaged or flawed diffusion aluminide coatings are repaired on a routine basis. The process of this invention is directed to the rejuvenation of the platinum-containing diffusion aluminide coating 20, and more particularly to removing at least a portion of the additive layer 22, such as when the additive layer 22 has been deposited to an excessive thickness in a process of rejuvenating the coating 20. The rejuvenation process of this invention is capable of removing the additive layer 22 without damaging the substrate material of the airfoil 12.

[0018] The repair process of this invention entails contacting the platinum-containing diffusion aluminide coating 20 with an acidic stripping solution containing phosphoric acid (H_3PO_4) and nitric acid (HNO_3). A suitable composition for the stripping solution is, by volume percent, about 25% to about 75% phosphoric acid containing about 85 weight percent H_3PO_4 (balance water), and about 25% to about 75% nitric acid containing about 75 weight percent HNO_3 (balance water). A preferred solution contains equal amounts of phosphoric and nitric acids at these specified concentrations, i.e., prepared by combining, by volume, about 50% phosphoric acid containing about 85 weight percent H_3PO_4 , and about 50% nitric acid containing about 75 weight percent HNO_3 . When a diffusion aluminide coating is contacted with the acidic stripping solution at a temperature of about 70°C to about 80°C (about 160°F to about 180°F), preferably about 75°C (about 170°F), for a duration of about 20 to about 30 minutes, preferably about 25 minutes, the additive layer 22 is stripped with a high level of selectivity with no measurable attack of the underlying superalloy substrate. Below the preferred temperature range, the activity of the solution is insufficient to remove the additive layer 22, while treatment temperatures above this range can result in attack of the superalloy substrate. The acid solution of this invention appears to selectively attack aluminum, particularly if the diffusion aluminide is a platinum aluminide, and therefore contains platinum intermetallics. While nitric acid and phosphoric acid are disclosed in U.S. Patent No. 3,833,414 to Grisik et al., their use was for a process of completely stripping a diffusion aluminide coating, and not for the limited purpose of completely removing an additive layer of a diffusion aluminide coating.

[0019] Because of the selectivity of the stripping solution to the aluminum of the additive layer 22, the invention enables the removal of an excessively thick additive layer (e.g., in excess of 100 micrometers), as may result from a rejuvenation process. The selectivity of the stripping solution is most advantageous if the coating 20 has not

seen high temperature service (i.e., the blade 10 has not been installed and operated in a gas turbine engine), so that limited interdiffusion has occurred between the blade superalloy, the additive layer 22 and the diffusion zone 24. Once the excess additive layer 22 of the original coating 20 is removed, a new additive layer of the desired thickness can be deposited without any risk of alloy depletion and thinning of the underlying substrate. A flash of platinum (e.g., about two micrometers in thickness) is deposited and diffused into the surface of the airfoil 12 exposed by the stripping operation (i.e., the diffusion zone 24 and any remaining portion of the original additive layer 22). A suitable process for diffusing the platinum layer is a thermal treatment of about two hours at about 1050°C (about 1925°F). A suitable re-aluminizing process is vapor phase aluminizing (VPA) performed at a temperature of about 1040°C (about 1900°F) for a duration of about six hours. Other diffusion aluminizing processes could be used, and are therefore within the scope of this invention.

[0020] During an investigation leading to the present invention, high pressure turbine (HPT) blades were treated with an acidic stripping solution of, by volume, about 50% phosphoric acid containing about 85 weight percent H_3PO_4 , and about 50% nitric acid containing about 75 weight percent HNO_3 . The blades were formed of a nickel-base superalloy known as René 142 and having a nominal composition, by weight, of about 12% cobalt, 6.8% chromium, 6.15% aluminum, 1.5% molybdenum, 4.9% tungsten, 6.35% tantalum, 2.8% rhenium, 1.5% hafnium, 0.12% carbon, and 0.015% boron, the balance nickel and incidental impurities. The blades were protected by a platinum aluminide coating that had been rejuvenated to form an additive layer whose thicknesses were in excess of 100 micrometers, which was deemed excessive for the particular application. The blades were contacted with the stripping solution at a temperature of about 170°F (about 75°C) for a duration of about twenty-five minutes, resulting in the additive layers being completely removed without damaging the underlying superalloy substrate. Following removal of the additive layers, a flash of platinum was plated on the exposed surfaces of the blades, which were then heat treated at about 1925°F (about 1050°C) to diffusion bond the platinum flash, and then re-aluminized by VPA at a temperature of about 1900°F (about 1040°C) for a duration of about six hours.

[0021] While the invention has been described in terms of a preferred embodiment, it is apparent that other forms could be adopted by one skilled in the art. For example, this invention is also applicable to a diffusion coating used as a bond coat for a thermal-insulating layer, as is often the case for high-temperature components of a gas turbine engine.

Claims

1. A process for rejuvenating a platinum-containing diffusion aluminide coating (20) on a component (10) following deposition of the diffusion aluminide coating (20) and before placing the component (10) in service at an elevated temperature, the diffusion aluminide coating (20) comprising an additive layer (22) on a surface of the component (10) and a diffusion zone (24) below the additive layer (22) and in a surface region of the component (10), the process comprising the steps of:

treating the diffusion aluminide coating (20) to an aqueous solution consisting essentially of nitric acid and phosphoric acid at a temperature of 70°C to 80°C until at least part of the additive layer (22) has been removed but the diffusion zone (24) remains, thereby establishing a treated surface of the diffusion aluminide coating (20);

depositing a platinum layer on the treated surface;

heat treating the component (10) to diffuse the platinum layer into the treated surface; and then aluminizing the treated surface of the component (10).

2. A process according to claim 1, wherein the aqueous solution consists of nitric acid, phosphoric acid and water.
3. A process according to claim 1, wherein the aqueous solution contains nitric acid and phosphoric acid in substantially equal proportions.
4. A process according to claim 1, wherein the diffusion aluminide coating (20) is treated for a duration of 20 to 30 minutes.
5. A process according to claim 1, wherein the aqueous solution is at a temperature of about 75°C and the diffusion aluminide coating (20) is treated for a duration of about 25 minutes.
6. A process according to claim 1, wherein the diffusion aluminide coating (20) is present on the component (10) as a result of aluminizing the component (10) after the component (10) has been placed in service at an elevated temperature.
7. A process according to claim 6, wherein the diffusion aluminide coating (20) is present on the component (10) at a thickness in excess of 100 micrometers prior to the treating step.
8. A process according to claim 1, wherein the component (10) is a gas turbine engine component (10),

and the diffusion aluminide coating (20) is present on the component (10) as a result of aluminizing the component (10) after the component (10) was installed on a gas turbine engine, the gas turbine engine was operated, and the component (10) was removed from the gas turbine engine.

9. A process according to claim 8, wherein the diffusion aluminide coating (20) is present on the component (10) at a thickness in excess of 100 micrometers after the aluminizing step and prior to the treating step.

10. A process according to claim 1, wherein the treating step removes substantially all of the additive layer (22) and does not damage the surface region of the component (10).

Patentansprüche

1. Verfahren zum Regenerieren einer Platin enthaltenden Diffusionsaluminidbeschichtung (20) an einem Bauteil (10) nach Abscheidung der Diffusionsaluminidbeschichtung (20) und vor Inbetriebnahme des Bauteils (10) bei einer erhöhten Temperatur, wobei die Diffusionsaluminidbeschichtung (20) eine Zusatzschicht (22) auf einer Oberfläche des Bauteils (10) und eine Diffusionszone (24) unter der Zusatzschicht (22) und in einem Oberflächenbereich des Bauteils (10) aufweist, wobei zu dem Verfahren die Schritte gehören:

Behandeln der Diffusionsaluminidbeschichtung (20) mit einer wässrigen Lösung, die im Wesentlichen auf Salpetersäure und Phosphorsäure basiert, bei einer Temperatur von 70 °C bis 80 °C, bis zumindest ein Teil der Zusatzschicht (22) entfernt ist, die Diffusionszone (24) jedoch verbleibt, so dass eine behandelte Oberfläche der Diffusionsaluminidbeschichtung (20) entsteht;

Abscheiden einer Platinschicht auf der behandelten Oberfläche;

Wärmebehandeln des Bauteils (10), um die Platinschicht in die behandelte Oberfläche zu diffundieren; und anschließend

Aluminisieren der behandelten Oberfläche des Bauteils (10).

2. Verfahren nach Anspruch 1, wobei die wässrige Lösung Salpetersäure, Phosphorsäure und Wasser enthält.
3. Verfahren nach Anspruch 1, wobei die wässrige Lösung Salpetersäure und Phosphorsäure mit im Wesentlichen gleichen Anteilen enthält.

4. Verfahren nach Anspruch 1, wobei die Diffusionsaluminidbeschichtung (20) für eine Zeitspanne von 20 bis 30 Minuten behandelt wird.
5. Verfahren nach Anspruch 1, wobei die wässrige Lösung eine Temperatur von etwa 75 °C aufweist, und wobei die Diffusionsaluminidbeschichtung (20) für eine Zeitspanne von etwa 25 Minuten behandelt wird.
6. Verfahren nach Anspruch 1, wobei die Diffusionsaluminidbeschichtung (20) als Ergebnis der Aluminisierung des Bauteils (10) an dem Bauteil (10) vorhanden ist, nachdem das Bauteil (10) mit einer erhöhten Temperatur in Betrieb genommen wurde.
7. Verfahren nach Anspruch 6, wobei die Diffusionsaluminidbeschichtung (20) an dem Bauteil (10) vor dem Behandlungsschritt mit einer Dicke von über 100 µm vorhanden ist.
8. Verfahren nach Anspruch 1, wobei das Bauteil (10) ein Gasturbinenbauteil (10) ist, und wobei die Diffusionsaluminidbeschichtung (20) an dem Bauteil (10) als Ergebnis der Aluminisierung des Bauteils (10) vorhanden ist, nachdem das Bauteil (10) in einem Gasturbinentriebwerk eingebaut war, das Gasturbinentriebwerk betrieben wurde, und das Bauteil (10) aus der Gasturbine entfernt wurde.
9. Verfahren nach Anspruch 8, wobei die Diffusionsaluminidbeschichtung (20) an dem Bauteil (10) nach dem Schritt des Aluminisierens und vor dem Schritt des Behandels mit einer Dicke von über 100 µm vorhanden ist.
10. Verfahren nach Anspruch 1, wobei der Schritt des Behandels die gesamte Zusatzschicht (22) im Wesentlichen entfernt und den Oberflächenbereich des Bauteils (10) nicht beschädigt

Revendications

1. Procédé de rajeunissement d'un revêtement d'aluminure de diffusion (20) contenant du platine sur un composant (10) à la suite du dépôt du revêtement d'aluminure de diffusion (20) et avant de mettre le composant (10) en service à une température élevée, le revêtement d'aluminure de diffusion (20) comportant une couche additive (22) sur une surface du composant (10) et une zone de diffusion (24) au-dessous de la couche additive (22) et dans une zone superficielle du composant (10), le procédé comportant les étapes de :

traitement du revêtement d'aluminure de diffusion (20) dans une solution aqueuse constituée

principalement par de l'acide nitrique et de l'acide phosphorique à une température de 70°C à 80°C jusqu'à ce qu'au moins une partie de la couche additive (22) ait été retirée mais de sorte que la zone de diffusion (24) reste, établissant ainsi une surface traitée du revêtement d'aluminure de diffusion (20) ;
dépôt d'une couche de platine sur la surface traitée,
traitement thermique du composant (10) pour diffuser la couche de platine dans la surface traitée ; puis
aluminage de la surface traitée du composant (10).

2. Procédé selon la revendication 1, dans lequel la solution aqueuse est constituée par de l'acide nitrique, de l'acide phosphorique et de l'eau.
3. Procédé selon la revendication 1, dans lequel la solution aqueuse contient de l'acide nitrique et de l'acide phosphorique en des proportions sensiblement égales.
4. Procédé selon la revendication 1, dans lequel le revêtement d'aluminure de diffusion (20) est traité pendant une durée de 20 à 30 minutes.
5. Procédé selon la revendication 1, dans lequel la solution aqueuse est à une température de 75°C environ et le revêtement d'aluminure de diffusion (20) est traité pendant une durée de 25 minutes environ.
6. Procédé selon la revendication 1, dans lequel le revêtement d'aluminure de diffusion (20) est présent sur le composant (10) en résultat de l'aluminage du composant (10) après que le composant (10) ait été mis en service à une température élevée.
7. Procédé selon la revendication 6, dans lequel le revêtement d'aluminure de diffusion (20) est présent sur le composant (10) en une épaisseur supérieure à 100 micromètres avant l'étape de traitement.
8. Procédé selon la revendication 1, dans lequel le composant (10) est un composant de turbomoteur à gaz (10), et le revêtement d'aluminure de diffusion (20) est présent sur le composant (10) en résultat de l'aluminage du composant (10) après que le composant (10) ait été installé sur un turbomoteur, le turbomoteur ait été mis en marche, et le composant (10) ait été déposé du turbomoteur.
9. Procédé selon la revendication 8, dans lequel le revêtement d'aluminure de diffusion (20) est présent sur le composant (10) en une épaisseur supérieure à 100 micromètres après l'étape d'aluminage et avant l'étape de traitement.

10. Procédé selon la revendication 1, dans lequel l'étape de traitement élimine sensiblement toute la couche additive (22) et n'endommage pas la zone superficielle du composant (10).

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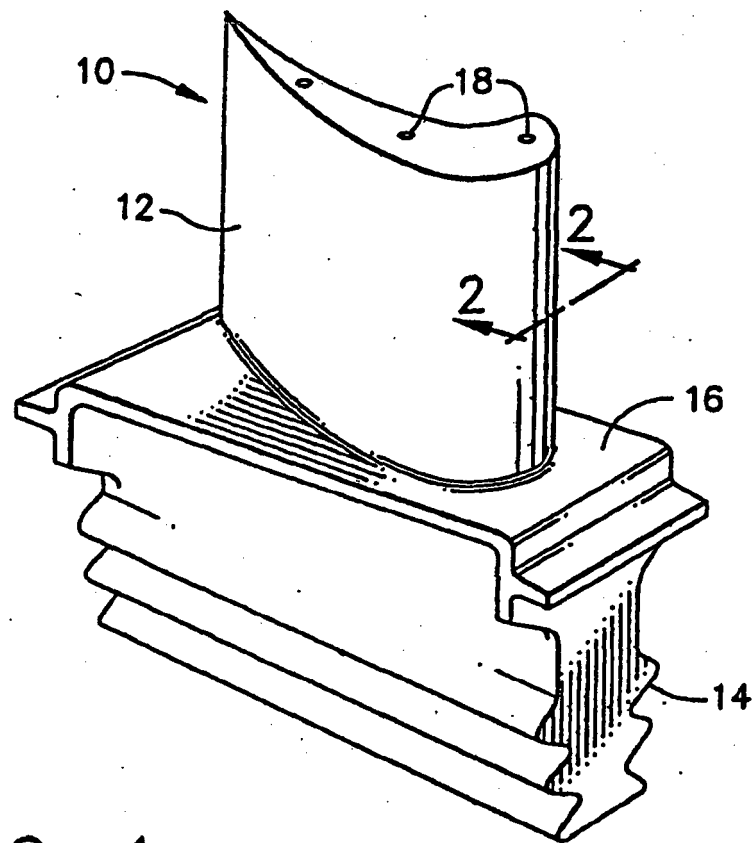


FIG. 1

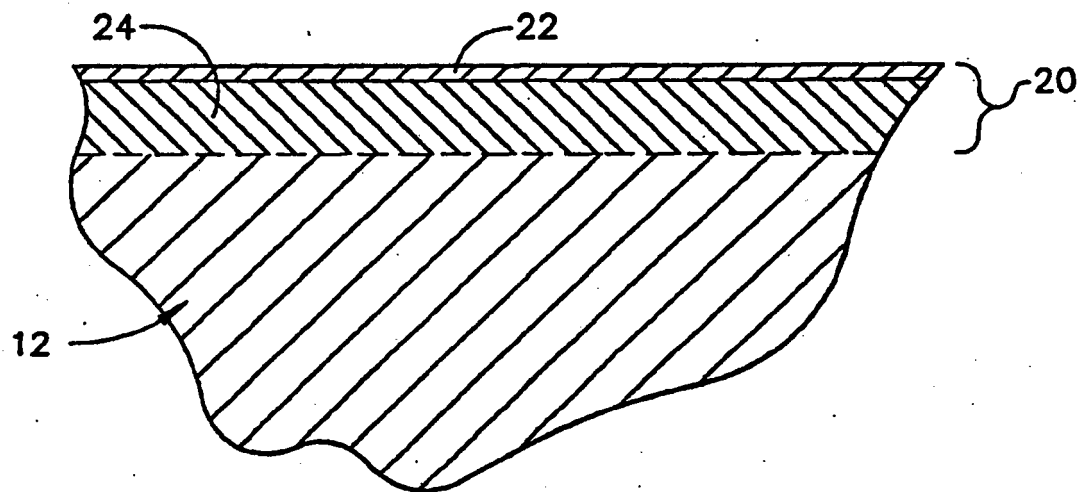


FIG. 2

REFERENCES CITED IN THE DESCRIPTION

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